COMPARATIVE HABITAT AND COMMUNITY RELATIONSHIPS OF *ATRIPLEX CONFERTIFOLIA* AND *SARCOBATUS VERMICULATUS* IN CENTRAL UTAH

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ABSTRACT.—Thirty-four study sites were established in shadscale (*Atriplex confertifolia* [Torr. & Frem.] Wats.) and greasewood (*Sarcobatus vermiculatus* [Hoov. Torr. in Emory) communities bordering Utah Lake in central Utah. Differences in species composition, vegetation, and soil characteristics were assessed. Significant differences in soil factors between the two communities were found for sand, calcium, manganese, zinc, and copper. Soluble salts and sodium concentrations were generally higher in the greasewood type, but differences were not significant. Major differences were found in understory species, with burr buttercup (*Ranunculus testiculatus* Grantz) showing significantly greater cover in the shadscale community and cheatgrass (*Bromus tectorum* L.) showing significantly greater cover in the greasewood community.

Shadscale (*Atriplex confertifolia* [Torr. & Frem.] Wats.) and Greasewood (*Sarcobatus vermiculatus* [Hook.] Torr. in Emory) are dominants of plant communities that cover vast areas of the Great Basin and are thus important components of our western rangelands. Recent research on these species has considered soil moisture relationships (Branson et al. 1976), evolution (Stutz 1978), phenology (roundy et al. 1981, Everett et al. 1980), faunal associates (Csuti 1979, Feldhamer 1980), grazing effects (Fetcher 1981), physiology (Caldwell et al. 1977), production (Van Epps et al. 1982), and successional relationships (Vasek and Lund 1980, Wallace and Romney 1980). However, there is a lack of information from central Utah concerning differences in community and habitat requirements of shadscale and greasewood. The purpose of this study was to compare habitats of shadscale and greasewood dominated sites in central Utah. Such information is valuable when attempting to manage those species in relationship to their use as forage for sheep on our winter ranges.

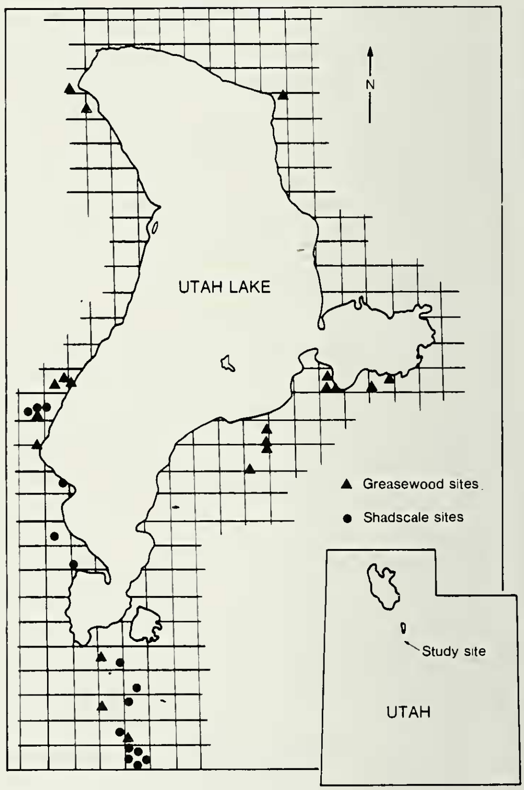

Fig. 1. Map showing the location of the 34 study sites near Utah Lake in central Utah.

STUDY AREA

Thirty-four study sites were sampled in shadscale and greasewood communities bordering Utah Lake, Utah (Fig. 1). Fifteen sites were studied in shadscale communities and nineteen in greasewood communities.

Shadscale communities are generally located on the west side of Utah Lake below the sagebrush zone and above or parallel to the

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greasewood zone. The overstory component of this community is dominated by shadscale. The understory is composed primarily of two introduced species, burr buttercup (*Ranunculus testiculatus*) and cheatgrass (*Bromus tectorum*).

Greasewood communities are found around the entire perimeter of Utah Lake but are best developed along the western shore. Overstory in this community is dominated by greasewood, and the understory is dominated by burr buttercup and cheatgrass. Both community types serve as winter range and spring lambing areas for several thousand head of sheep each year.

Climatic conditions at the study sites are characterized by hot dry summers and cold winters. Average annual precipitation varies from 190 to 290 mm, with 60% falling in the winter and early spring months. The hottest month of the year is July, with an average of 33 C; the coldest month is January, with an average of 3 C. The frost-free period for the area ranges from 132 to 170 days (Swenson et al. 1972).

METHODS

Study areas were selected to represent a range of environmental conditions in shadscale and greasewood communities of central Utah. Once a site was located, a 10 x 10 m macroplot (0.04 ha) was randomly located within each area. Elevation, percent slope, slope position, and soil erosion were noted for each site. Each plot was subsampled with 20 $0.25 m^2$ quadrats (microplots) stratified across the macroplot in five rows of four quadrats each. Data were taken during May and June 1980.

Total living cover, plant cover by life form, litter, exposed rock, and bare ground were estimated at each microplot following ocular procedures suggested by Ostler (1980). Cover of individual plant species encountered was also estimated using cover class categories suggested by Daubenmire (1959). All species occurring within a macroplot but not in any microplots were listed and given a percentage cover value of 0.01. All species encountered were classified as to life form, longevity, and whether native or introduced in the Utah flora.

Three soil samples were taken in each macroplot (from opposite corners and the center) from the top 20 cm of soil and later combined for laboratory analysis. This depth was considered adequate based on Ludwig's results (1969), which showed that the surface decimeter of soil yields 80% of the information useful in correlating plant response with concentrations of essential mineral nutrients in the soil. Studies by Holmgren and Brewster (1972) also showed that greater than 50% of the fine roots are found in the top 15 cm of soil profiles in desert shrub communities in western Utah.

Soil samples were analyzed for texture (Bouyoucos 1951), pH, soluble salts, mineral composition, and organic matter. Soil pH was determined with a glass electrode pH meter. Soluble salts were determined with a Beckman electrical conductivity bridge. Exchangeable calcium, magnesium, potassium, and sodium were extracted from soils with DTPA (diethylene triamine-penta-acetic acid) (Lindsay and Norvell 1969). A Perkin Elmer Model 403 atomic absorption spectrophotometer was used to determine individual ion concentrations (Isaac and Kerber 1971). Phosphorus was extracted with sodium bicarbonate (Olsen et al. 1954). Nitrogen analysis was made using macro-Kjeldahl procedures (Jackson 1958). Organic matter was estimated from total carbon using methods described by Allison et al. (1965).

Means, standard deviations, and coefficients of variation were determined for each biotic or abiotic variable across the 34 sampling plots. Prevalent species were determined following Warner and Harper (1972) on the basis of cover values. One-way analysis of variance was used to detect significant differences between the two communities with reference to 18 different soil variables. Student's t-test was used to detect significant differences in site characteristics and biotic factors between the two communities. Taxonomic determinations for all plant species included in our study follow Arnow et al. (1980).

RESULTS AND DISCUSSION

Significant differences between factors of the shadscale and greasewood communities near Utah Lake existed for only two of the

TABLE 1. Means, standard deviations, and coefficients of variation of general site characteristics for shadscale and greasewood communities around Utah Lake (N = 34).

	Shadscale			Greasewood		
Site characteristics	Mean	S.D.	C.V.	Mean	S.D.	C.V.
Elevation	4524.53	17.94	0.003	4530.75	45.75	0.01
Percent slope	.73	1.44	1.97	0.95	1.76	1.28
[a]Slope position*	1.47	0.83	0.57	2.15	0.93	0.43
[b]Erosion	0.00	0.00	0.00	0.05	0.22	4.40
Percent litter cover**	5.20	3.90	0.75	2.95	4.33	1.47
Percent exposed rock	0.00	0.00	0.00	0.02	0.07	3.39
Percent exposed soil	16.07	14.65	0.91	12.56	11.33	0.90

[a]Slope position is defined as 1 = top of slope, 2 = midslope, 3 = bottom of slope.
[b]The erosion index runs from 0 to 3, with 0 indicating no erosion and 3 heavy.
*Significant differences between means at 0.10 level.
**Significant difference between means at 0.05 level.

TABLE 2. Means, standard deviations, and coefficients of variation of cover of prevalent species in shadscale and greasewood communities around Utah Lake (N = 34).

	Shadscale			Greasewood		
Species	Mean	S.D.	C.V.	Mean	S.D.	C.V.
Atriplex confertifolia	16.80*	8.71	0.52	0.24*	0.89	3.70
Bromus tectorum	10.77*	9.25	0.86	35.38*	27.69	0.78
Cardaria draba	0.00	0.00	0.00	5.68*	14.74	2.60
Ephedra viridis	2.01*	6.83	3.40	0.00	0.00	0.00
Halogeton glomeratus	1.89*	4.23	2.24	1.24	5.48	4.42
Hordeum leporinum	0.00	0.00	0.00	5.62*	14.74	2.62
Kochia americana	5.67*	8.05	1.43	0.00	0.00	0.00
Kochia scoparia	1.75*	6.27	3.58	7.47*	13.13	1.76
Lepidium perfoliatum	8.71*	6.86	0.79	7.82*	8.45	1.08
Ranunculus testiculatus	60.77*	25.78	0.42	23.25*	25.99	1.11
Salsola iberica	0.01	0.04	4.00	3.26*	6.55	2.00
Sarcobatus vermiculatus	2.22*	3.11	1.40	28.88*	14.62	0.51
Sitanion hystrix	0.99	1.56	1.58	2.39*	5.07	2.12
Suaeda calceoliformis	0.01	0.03	3.00	3.75*	13.11	3.50
Suaeda torreyana	1.35*	2.40	1.77	2.69*	6.10	2.27

*Prevalent species

eight general site variables considered (i.e., slope position and percent cover, Table 1). Shadscale had greater litter cover and tended to occupy upper slope positions, whereas greasewood was found at midslope positions.

Shadscale and greasewood communities had six prevalent species in common (Table 2). Cover of annual plants was 66% and 52% in the shadscale and greasewood communities, respectively (Table 3). These cover values represented 72% and 65%, respectively, of the total living cover of those two communities. The cover values for burr buttercup and cheatgrass were of particular interest. The greasewood and shadscale communities considered herein had been heavily impacted for many years by domestic grazing animals (Table 3). Such sustained overuse would open up areas within the community and allow these introduced species to invade and develop high cover values. The area is used as late winter and early spring sheep range, and sustained overuse is the suggested cause for deteriorated range condition at most of the sites (Brotherson and Evenson 1982). Grazing estimates were based on the condition of plants and soils and their relative responses to grazing (Stoddart et al. 1975).

The shadscale community had significantly greater burr buttercup cover and significantly less cheatgrass cover than the greasewood community. Burr buttercup (Table 2) contributed 60% cover, whereas cheatgrass contributed only 10% in shadscale plots. Conversely, the greasewood community contained significantly greater amounts of cheatgrass. Other annual forbs, (Belvedere summer cypress, *Kochia scoparia*, Haloge-

TABLE 3. Means, standard deviations, and coefficients of variation for biotic factors in shadscale and greasewood communities (N = 34).

	Shadscale			Greasewood		
	Mean	S.D.	C.V.	Mean	S.D.	C.V.
Total living cover	79.4	14.50	0.18	80.7	16.12	0.20
% Shrub cover	14.1	6.00	0.43	20.3	10.13	0.50
% Subshrub cover**	8.4	12.87	1.54	2.9	8.71	2.93
% Perennial forb cover**	0.0	0.00	0.00	3.3	7.27	2.23
% Perennial grass cover**	2.2	2.15	4.91	5.3	8.05	1.53
% Annual grass cover***	8.4	5.90	0.71	26.2	21.15	0.81
% Annual forb cover***	57.7	21.06	0.37	29.3	22.67	0.77
% Total annual cover***	66.1	19.50	0.30	52.2	21.53	0.41
% Cryptogam cover*	9.4	6.61	0.71	6.8	6.85	1.01
Diversity	1.9	0.42	0.22	2.2	0.48	0.22
Number of species/quadrat	0.5	0.12	0.28	0.5	0.16	0.31
Number of species/stand	9.1	2.71	0.30	10.3	3.21	0.31
Number of native species/stand	4.9	1.92	0.39	5.5	2.93	0.53
Number of introduced species/stand	4.2	1.42	0.34	4.8	1.70	0.36
Percent of flora:						
Native species	52.5	12.67	0.24	51.7	16.49	0.32
Introduced species	47.5	12.67	0.27	48.4	16.49	0.34
Percent of total cover:						
Native species**	27.9	19.08	0.68	34.6	17.37	0.50
Introduced species**	72.1	19.08	0.26	65.4	17.37	0.27
Grazing impact	2.5	0.74	0.29	2.5	1.00	0.40

*Significant difference between means at 0.10 level.
**Significant difference between means at 0.05 level.
***Significant difference between means at 0.01 level.

ton–*Halogeton glomeratus*, and clasping pepperweed, *Lepidium perfoliatum*) showed different patterns of distribution. Halogeton and clasping pepperweed were evenly distributed in both communities, whereas Belvedere summer cypress showed much greater cover in the greasewood type.

Other grass species—rabbit barley (*Horidum leporinum*) and bottlebrush squirreltail (*Sitanion hystrix*)—showed patterns similar to cheatgrass. Reasons for these relationships are unknown. Edaphic factors may be partially responsible for site selection of the two annuals (burr buttercup and cheatgrass). This is shown in the distribution patterns of the two species when their cover values are plotted against the different soil factors (Fig. 2). As shown, the two species exhibit different patterns with respect to percent sand, percent silt, percent fines, pH, nitrogen, calcium, iron, zinc, and copper. The species patterns with respect to the textural classes appear as mirror images of each other; therefore, the relationship is probably due to species interactions rather than cause and effect with respect to the soil factor itself. The species distribution patterns with respect to pH, nitrogen, calcium, iron, zinc, and copper are more disjunct and, therefore, may suggest cause and effect relationships. When we examine these factors with respect to their distribution between the two community types, the differences in calcium, zinc, and copper are shown to be significantly different. However, the lack of significant differences between the majority of the soil factors measured and the rather large coefficients of variation attached to these same variables suggest that the exhibited differences in distribution may be a function of which species first invaded and became established. Once established, species such as burr buttercup and cheatgrass may be highly competitive to other species. Competitive relationships between these two annuals would certainly follow invasion and may, therefore, be responsible for the observed distributions. Burr buttercup has been suspected to be allelopathic (an inhibitor of seed germination of other species through release of harmful chemicals into the soil) (Buchanan et al. 1978). Further evidence of the competitive nature of burr buttercup can be seen by examining the prevalent species lists for the two community types (Table 2). The greasewood type contained six prevalents that exhibited much greater cover values

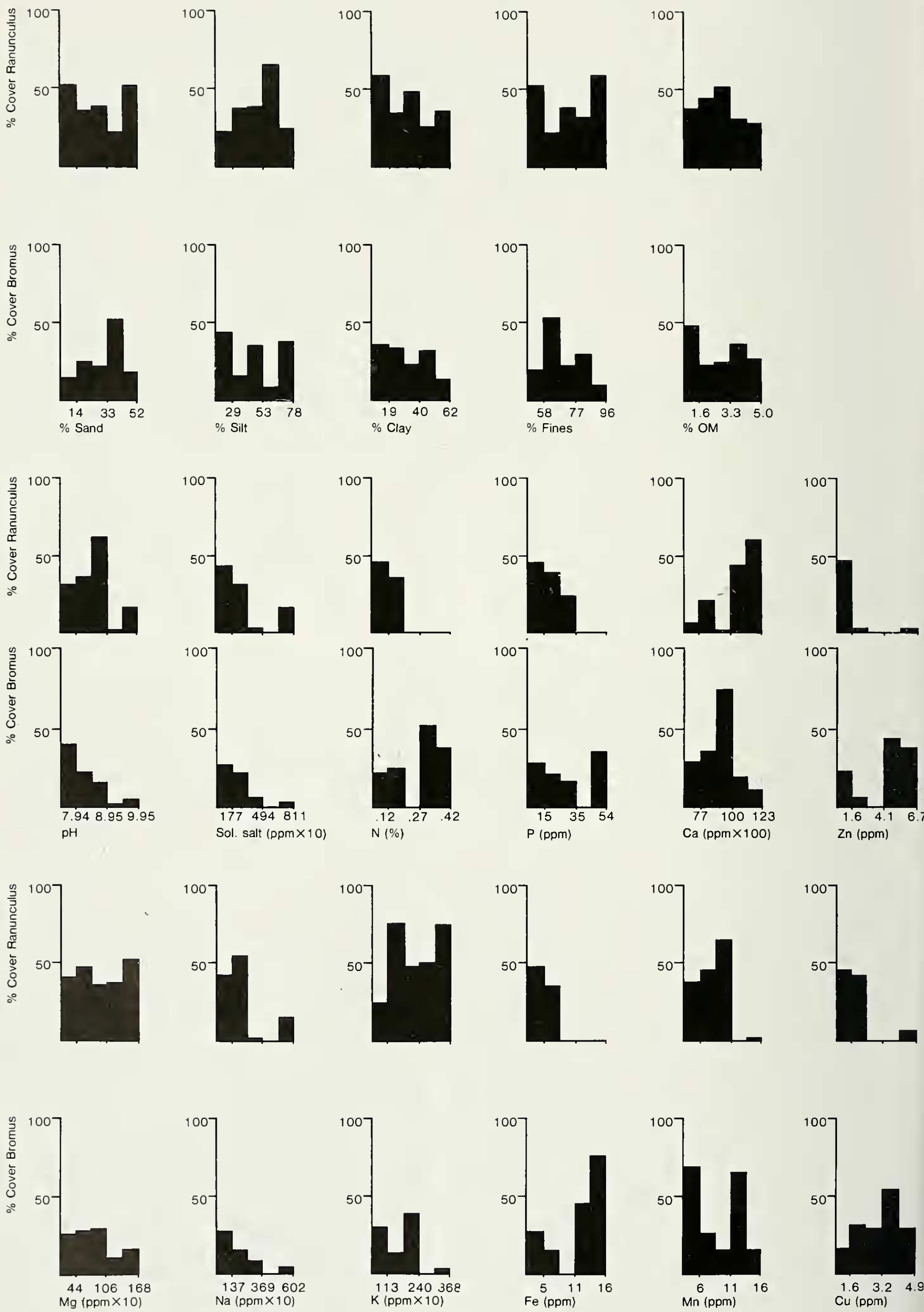

Fig. 2. Cover of *Ranunculus testiculatus* and *Bromus tectorum* plotted against major soil gradients of study sites.

TABLE 4. Means, standard deviations, and coefficients of variation of observed soil characteristics in shadscale and greasewood communities.

	Shadscale			Greasewood		
Soil characteristics	Mean	S.D.	C.V.	Mean	S.D.	C.V.
Percent sand*	16.53	8.43	0.51	27.33	16.15	0.59
Percent silt	43.20	8.58	0.20	39.90	15.48	0.39
Percent clay	40.27	10.50	0.26	32.78	12.38	0.33
Percent fines*	83.47	8.43	0.10	72.68	16.15	0.22
Percent organic matter	2.57	0.86	0.33	2.66	1.00	0.38
pH	8.06	0.90	0.11	8.21	0.60	0.07
Soluble salts (ppm)	614.20	259.03	0.42	1502.35	2156.21	1.44

*Significant difference at .05 in the means.

TABLE 5. Means, standard deviations, and coefficients of variation of soil nutrient in shadscale and greasewood communities.

	Shadscale			Greasewood		
Soil nutrient	Mean	S.D.	C.V.	Mean	S.D.	C.V.
Percent nitrogen	0.11	0.04	0.37	0.13	0.09	0.72
Phosphorus (ppm)	13.70	5.62	0.41	18.60	11.31	0.61
Calcium (ppm)***	11146.70	518.23	0.05	9062.30	1675.29	0.18
Magnesium (ppm)	786.90	355.39	0.45	607.80	409.31	0.67
Sodium (ppm)	613.10	331.78	0.54	1031.20	1566.45	1.52
Percent Na saturation	4.34	2.20	0.51	8.64	12.14	1.40
Potassium (ppm)	1364.30	772.01	0.57	921.00	598.08	0.65
Iron (ppm)	4.30	0.98	0.23	5.80	3.56	0.62
Manganese (ppm)*	6.60	1.56	0.24	8.70	3.54	0.41
Zinc (ppm)*	0.62	0.29	0.47	1.70	1.75	1.06
Copper (ppm)**	1.30	0.38	0.30	2.20	1.22	0.55

*Significant at .05 level in the means.
**Significant at .01 level in the means.
***Significant at .001 level in the means.

on the greasewood sites than on the shadscale sites. The shadscale community, on the other hand, had only two prevalents that showed greater cover on the shadscale than on the greasewood sites. Both of these species were shrubs. If burr buttercup is as allelopathic to cheatgrass as it is to other grass species, then burr buttercup should have a competitive advantage. However, further study is needed concerning the factors involved in the distribution of these two introduced annuals before the question can be fully answered.

Soils from the greasewood community had significantly more sand than soils from shadscale stands (Table 4). No significant differences were found for percent silt or percent clay in these communities, but, when combined, silt and clay (fines) were significantly greater in the shadscale community. We suspect that the sifting effects of currents at high water levels of the lake in the distant past, may have been responsible for larger percentages of sands in the greasewood type in this study.

Mineral nutrient concentrations in the shadscale stands were greater than have been previously reported (El-Ghonemy et al. 1980). Sodium, zinc, and nitrogen were approximately 1.2 times greater in our study area, manganese was 3.4 times greater, and copper was 8.1 times greater. Even larger differences were found for phosphorus and iron concentrations, which were approximately 26 times greater in our study area than in the Mojave Desert areas studied by El-Ghonemy et al. (1980). Calcium and magnesium concentrations combined were 6.8 times greater in our study area. Potassium was the only ion reported to have greater concentrations in Nevada than in our study area in Utah. Comparable soil data were not found in the literature for comparison with our results from greasewood sites.

Significant differences between shadscale and greasewood communities at the Utah Lake site were found for calcium, manganese, zinc, and copper (Table 5). Calcium was sig-

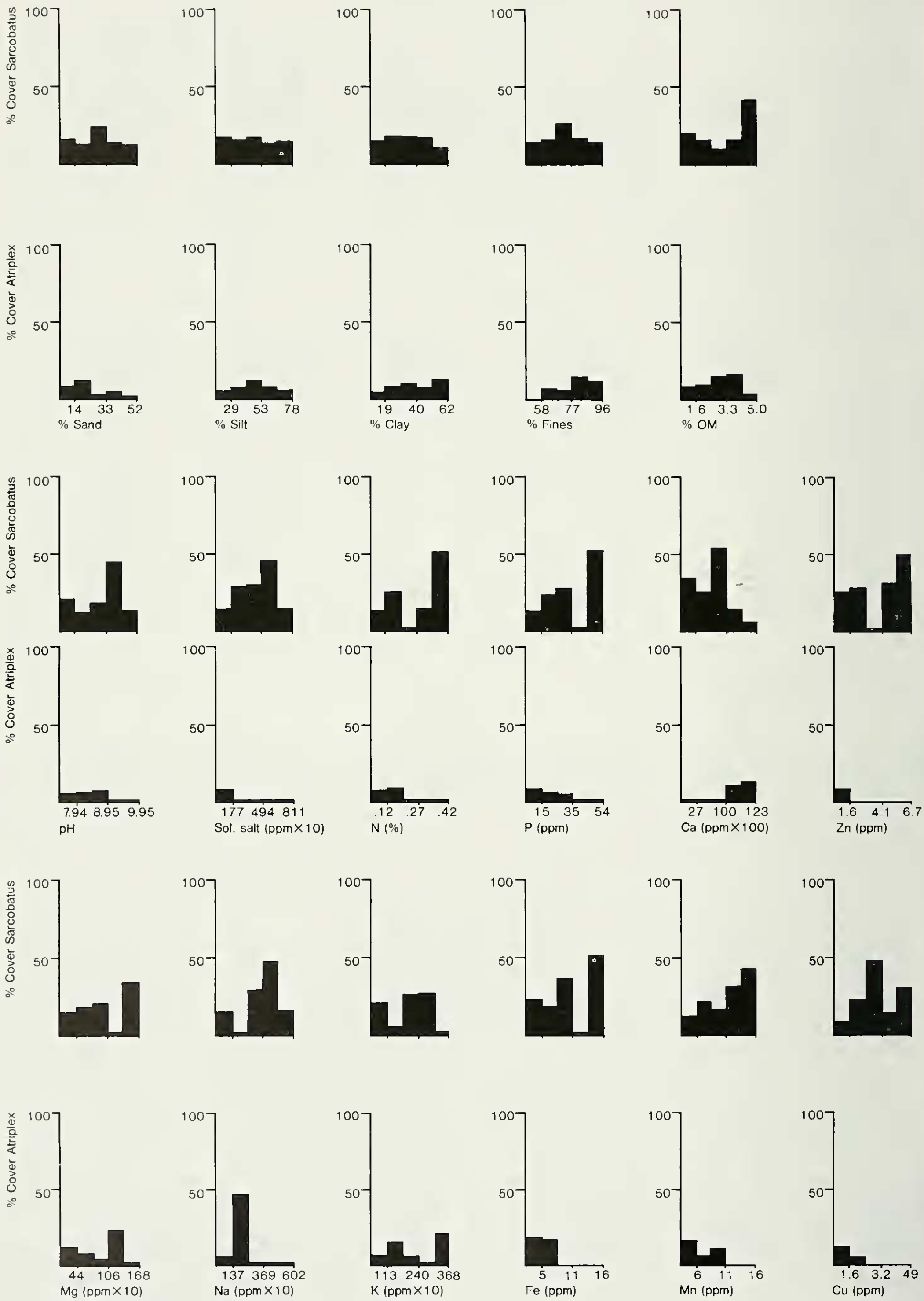

Fig. 3. Cover of *Sarcobatus vermiculatus* and *Atriplex confertifolia* plotted against major soil gradients of study sites.

TABLE 6. Species preferences indices with respect to measured soil factors.

Site factor	Species			
	Sarcobatus vermiculatus	*Atriplex confertifolia*	*Ranunculus testiculatus*	*Bromus tectorum*
Sand (%)	21.4	17.2	19.6	24.7
Silt (%)	42.5	42.7	44.4	40.2
Clay (%)	35.4	40.3	36.0	34.5
Fines (%)	78.0	83.1	80.4	74.7
Organic matter (%)	2.8	2.8	2.5	2.7
pH	8.2	8.2	8.2	8.0
Soluble salts (%)	1,526.4	720.2	718.4	665.2
Nitrogen (%)	.14	.12	.11	.13
Phosphorus (ppm)	21.5	14.2	23.4	15.9
Calcium (ppm)	9,343.9	11,116.1	10,729.6	9,498.7
Magnesium (ppm)	649.0	852.7	664.9	620.0
Sodium (ppm)	1,057.8	730.0	631.2	457.1
Potassium (ppm)	987.7	1,333.4	1,384.8	910.3
Iron (ppm)	6.4	4.4	4.0	5.6
Manganese (ppm)	9.3	6.5	6.9	7.9
Zinc (ppm)	1.9	.59	.75	1.7
Copper (ppm)	2.3	1.2	1.5	1.2

nificantly greater in the shadscale community. Since the shadscale sites occurred at the top of slopes and greasewood sites occupied midslope areas (Table 1), Romney and Wallace's (1980) contention that calcium tends to dominate the soluble cation complex at upland positions is supported. We suspected that total soluble salts and concentrations of sodium would be significantly greater in the greasewood community (Fireman and Hayward 1952). However, significant differences were not observed, although salt concentrations were higher at some greasewood sites. Percent sodium saturation was also greater in the greasewood community, but differences between communities was not statistically significant. This is best explained in terms of slope position. As indicated by Romney and Wallace (1980), sodium should dominate only at the bottom of slopes in closed drainage basins. In our study sites greasewood was not located within a closed drainage basin, but instead at midslope positions (Table 1).

Copper, zinc, and manganese concentrations were all significantly greater in soils from the greasewood community, which suggests that there may be greater availability of these nutrients to greasewood than to shadscale. However, since no data are available on the nutritional needs of greasewood and shadscale, no judgement can be made as to the role different concentrations might play in the distribution patterns of species within the two communities. In any event, these minerals accounted for detectable differences between shadscale and greasewood habitats in central Utah.

To better understand the microhabitat variation between greasewood and shadscale, their percent cover was plotted against the measured soil factors (Fig. 3). Variation in each soil factor (percent sand, organic matter, calcium, etc.) was considered as a gradient. Measured values for all sites were ranked and the corresponding species cover values were plotted against the gradient. This procedure allowed visualization of the point along the gradient where each species was most important as measured by percent cover. With this approach, one is able to visualize those factors that may be important in niche separation. In our case differences existed between greasewood and shadscale for soluble salts, nitrogen, phosphorus, calcium, zinc, sodium, iron, manganese, and copper. Where a species exhibits distinctive patterns with respect to a soil gradient, we may postulate some degree of cause and effect relationship. Conversely, if the species showed no patterns of restriction, but was randomly spread across the gradient, we postulate that the species distribution is probably not affected by that factor. It is possible that strong patterns may exist along a gradient and yet not be due to a causal relationship. Rather, the pattern could be due to some other environmental factor closely correlated to the gradient factor in question. In some cases, patterns in species distribution may also relate to patterns in a complex of habitat factors rather than to any single factor.

Shadscale showed rather narrow ranges of distribution with respect to the micronutrients (zinc, iron, manganese, and copper) but generally grew across the full extent of all the other gradients. Greasewood showed rather broad tolerance ranges across all the gradients (Fig. 3).

To further elucidate the relationships associated with the observed distribution patterns of the four species (burr buttercup, cheatgrass, shadscale, and greasewood), we computed species preferences indicies (Skougard and Brotherson 1979) for these species in conjunction with all measured soil factors (Table 6). As shown, the species show different preference indicies for soil factors, texture (sand and fines), soluble salts, phosphorus, calcium, sodium, potassium, iron, manganese, zinc, and copper. Whether these differences are of sufficient magnitude to be causal with respect to the observed differences in the distribution patterns of these species is not clear. However, the differences are detectable and in some cases are of sufficient magnitude that, when coupled with the other evidences discussed in this paper, they aid us in better understanding that differences do exist in the habitats of the two community types.

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